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Articles PAGE

Perpetual and Mental Calendars ..... *C. E. White* 233

Perpetual Ecclesiastical Calendars ..... *C. E. White* 241

The Visual Photometry of Variable Stars (conclusion) ..... *H. Boyd Brydon* 249

Improved Telescope Spider Design ..... *C. H. Werenskiold* 268

An Early Reference to an Astronomical Event Comes to Light (with Plate XI) ..... *W. Kenneth Angus* 271

Review of Publication

The Analytical Foundations of Celestial Mechanics, by Aurel Wintner *A. F. Stevenson* 273

Notes and Queries

Morehouse and His Comet—A Research Physicist's Views on Education—The Moon and the Weather—Personal Notes....*C.A.C.* 274

Meetings of the Society

At Victoria, Jan. 1941 280

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PERPETUAL AND MENTAL CALENDARS

By C. E. WHITE

WEBSTER'S *International Dictionary* and Funk and Wagnalls' *Standard Dictionary* define a perpetual calendar as one that enables a person to find the day of the week on which any date of the past fell or on which any date of the future will fall. This definition agrees with the structure and use of these calendars in the past, but this article will show that the definition is incomplete because such calendars can be so constructed that the problem of finding the calendar date of the current day is emphasized and is practicable.

Perpetual calendars are of two types: the table type, and the rule-and-formula type. The first perpetual calendar of the table type was probably invented by Clavius or Lillius during the sixteenth century. A better form, independent of finding the Dominical letter, was constructed by John Herschel near 1850. There are other forms of this type to be found in mathematical journals, but in this article the rule-and-formula type is emphasized because it is more practical.

The second type was probably first discovered by the Venerable Bede[1] and published in Latin in his *Almanac* during the eighth century. Bede was a priest and it appears that the method may have been known only to priests for many years. A very extensive inquiry for old almanacs in *Notes and Queries*, a famous London publication, resulted in the conclusion that the oldest in the manuscript form was written in 1300 and the oldest almanac known to have been printed in England was the Sheapheards Kalendar printed by Richard Pynson in 1497.[2] Thus it appears that Bede's

[1]He is known as the Father of English History.

[2]Chambers, *Book of Days*, Vol. I, p. 10, also mentions this printing.

Almanac had disappeared from libraries and the shops of antiquaries. However there appeared in *Notes and Queries*, 1851, an article by A. E. B., of Bristol, England, giving Bede's perpetual calendar, with changes to make it applicable to the Gregorian calendar. The method of Bede and of A. E. B. is not referred to by any index of mathematical or astronomical literature, and it seems that, without knowledge of these methods, a similar method was discovered by E. B. Elliott in 1873, and it was published in the *Smithsonian Miscellaneous Papers* in 1875, where it was hidden from the lexicographers for half a century. The rule now appears in the last editions of Webster's *International* and Funk and Wagnalls' *Standard* dictionaries, but the compilers of encyclopedias haven't found it yet. Elliott's derivation of his method was not given in *Miscellaneous Papers*.

In 1898 Royer in his *Higher Mental Arithmetic* published a rule without giving its derivation. He may have derived it independently, or by subtracting 2 from Elliott's century numbers and adding 2 to his month numbers. A few methods have been published this century but they are almost as closely related to Elliott's as is Royer's. The general scheme is as follows: represent the *day of the month* by a number, the *month* by a number, the *year of the century* by a number, and the *century* by a number, determined so as to measure the effect of each of these factors on the day of the week. Add the four numbers, divide by 7, and the remainder will give the day of the week.

In deriving, in 1923, Royer's method for my class, I observed that the Christian era commenced on Saturday. The *first* day of the *first* month of the *first* century was on the *seventh* day of the week. I observed that $1+1+1+4=7$ and then determined how each of these numbers changes as time marches on. Thus, I derived what I now know to be Elliott's method, and then derived Royer's method from the similarity mentioned above. If I had let $1+2+1+3=7$, I would have derived A. E. B.'s method. Had I let $1+0+1+5=7$, I would have derived Johnson's method. If I had let Saturday be the sixth day of the week, I would have derived other methods.

The above methods, although much alike in the main characteristic, differ in minor characteristics. Thus, in nomenclature

Elliott's ***number*** is Bede's ***regular***, is Royer's ***ratio***, is Jones's[3] ***characteristic***, and White's[4] ***addend*** with the exception of a common difference in numerical values. Elliott, Zeller[5] and White use different formulas for computing the century number, Zeller and Johnson[6] give formulas for computing the month numbers. Bede gives a mnemonic for determining the regulars and White emphasizes that Elliott's month numbers written as a series are:

$$144, 025, 036, 146$$

or

$$12^2,\ 05^2,\ 06^2,\ 12^2+2,$$

which is easily remembered. White emphasizes a method of finding the calendar date by first finding the day of the week on which the 7th, 14th, 21st, and 28th fall, these dates being chosen because the day addend for them is zero. If the 7th falls on Wednesday, we know that Friday would be the 9th. In this method, since the day and century addends are zero, it was only necessary to add together the month and year addends and when one of these happened to be zero, the process was very simple. The simplicity of the above series made a mental calendar possible. In each of the methods, the year number is found by adding to the year-of-century number its one-fourth, omitting fractions, and then subtracting from the sum that multiple of 7 that will give a number less than 7.

Example.—Let us consider the date March 5, 1941.

(1) *The day addend* is 5. If the date were March 24 the day addend would be 24, or its equivalent 3.

(2) The *month addend* is 4. This number is the third in the series in the previous paragraph, March being the third month.

(3) The *year addend* is given by the formula

$$\left[\frac{41+[41/4]_q}{7}\right]_r=2.$$

A bracket with q as "sub" means that the integral part of the quotient is to be used. Thus $[41/4]_q=10$. If the "sub" is r, the remainder is to be used. Thus $[(41+10)/7]_r=[51/7]_r=2$.

[3] *School Science and Mathematics.*

[4] *Journal of The Mathematical Association of Japan*, Jan. 1925; *Popular Astronomy*, Jan. 1927.

[5] *Bulletin de La Société Mathematique de France*, 1883.

[6] *Nature*, 1906.

(4) The *century addend* is given by $6-2[19/4]_r=0$ for the present century. This formula is given in (2) page 237.

Then, since $[(5+4+2+0)/7]_r=4$, the day of the week is the fourth, or Wednesday.

In the above methods the problem has been to find the day of the week of a calendar date. We shall now derive three methods where the problem is to find the calendar date. This century began on Monday and it is easily shown that the date of the *first* Sunday of each of the twelve months was, respectively,

Jan.	Feb.	Mar.	April	May	June
8−1	8−4	8−4	8−0	8−2	8−5
July	Aug.	Sept.	Oct.	Nov.	Dec.
8−0	8−3	8−6	8−1	8−4	8−6 . . . (1)

except that the April and July dates are the dates of the *second* Sunday of those two months. I use 8−1 instead of 7, 8−4 instead of 4, and so on, because the series,

144, 025, 036, 146,

is much easier to remember than the other series. In passing from a common year to another common year the dates relative to the week drop back one day, and in passing from a common year to a leap year, the dates relative to the week drop back two days except for January, and February, and in passing from a leap year to a common year the dates drop back two days for January and February, and one day for the other months. This recession can be expressed as follows: Let y be the year of the century, then it is easily seen that the recession will be the remainder found by dividing $y+[y/4]_q$ by 7, except that the remainder must be decreased by 1 for January and February of leap years.

It is convenient also to make use of the notation $A\equiv B \bmod 7$, which means that if both A and B be divided by 7 the remainders will be the same; or, if r be the remainder, $r\equiv B \bmod 7$, which means that B days from Sunday gives the same day of the week that r days would give. Having our problem in mind we could say r is the least positive equivalent of B or $B\equiv r$.

If k be the number less than 7 which is to be subtracted, Jan$(8-1-k)$ will be the date of the first Sunday in January, etc.

We can get the date of any other Sunday by adding a multiple of 7. If we wish to find the date of any other day of the week we must add w, the number of the day counting Monday 1. It is easy to remember that Sun. is 7 or 0 and that Mon. is 1, that the number for Tu., Wed., or Thur. is the same as the number of letters in the abreviations (i.e., 2, 3 or 4), that Fri. and five begin with the same letter and that Sat. and six also begin with the same letter. Since the century correction is a year correction,[7] it is evident that the century number c should be subtracted. Inserting these corrections in (1) we get:

$$\text{Jan.}(8-1-k-c+7n+w),\quad \text{Feb.}(8-4+s),\quad \text{Mar.}(8-4+s),$$
$$\text{Apr.}(8+s),\quad \text{May}(8-2+s),\quad \text{June}(8-5+s),\quad \text{July}(8+s),$$
$$\text{Aug.}(8-3+s),\quad \text{Sep.}(8-6+s),\quad \text{Oct.}(8-1+s),$$
$$\text{Nov.}(8-4+s),\quad \text{Dec.}(8-6+s),\ \ldots\ldots\ldots\ldots\ldots\ (2)$$

where $s=-k-c+7n+w$.

In the above, the century correction can be determined in three ways by empirical formulas:

(1) When C is odd, $c=2[(C+1)/4]_r$, and when C is even $c=2[(C-1)/4]_r$.

(2) $c=6-2[C/4]_r$, used by A. E. B. of Leeds (1851) and by Elliott (1873).

(3) $c=[C/4]_q-2C+6$, used by Zeller, with the exception that he used 5 instead of 6, but this is explained by observing that each of his month numbers is 1 greater than the corresponding Elliott numbers.

Observe that a small c is used to represent the century addend, while a capital C is used to represent the century. Thus for this year C is 19, c is 0 (obtained from formulas 2 or 3 above).

Equating the last two values of C, we make an interesting discovery,

[7] Instead of letting 4 be the century addend for the first century of the present Era, Bede let 4 be the sun's epact, which is the century addend plus the year addend for any year by finding the remainder when $(4+y+[y/4]_q)$ is divided by 7 where y represents the entire year instead of the year of the century. Because there is at present a difference of 13 days between the Gregorian and Julian calendars, it would be necessary now to subtract 13. Mr. A. E. B. was probably the first to make two numbers of it—one for the century and the other for the year of the century.

$$[C/4]_q - 2C + 6 \equiv 6 - [C/4], \bmod 7$$

or
$$[C/4]_q \equiv 2C - 2[C/4], \bmod 7^8 \quad \ldots\ldots\ldots (3)$$

To make use of this discovery, we write the formula for the date of the first Sunday in March in full—

$$\text{Mar.}(8 - 4 - y - [y/4]_q + 2[C/4], - 6) \quad \ldots\ldots (4)$$

Since (3) is true, $[y/4]_q \equiv 2y - 2[y/4],$.
Substituting in (4), we have

$$\text{Mar.}(8 - 4 - 3y + 2[y/4], - c) = \text{Mar.}(4[y/7], + 2[y/4], - c - 3).$$

From the Sunday dates in (2), we observe that 3 must be added to get the April date, etc. In this way, we determine the series:

$$3,0,0,\ 4,2,-1,\ 4,2,-2,\ 3,0,-2.$$

To find the date of the first Sunday of the 4th month add the 4th number of the series to $4[y/7], + 2[y/4], - 3$. If M stands for the month and m for the month number, any calendar date is determined by the formula

$$\text{M}(4[y/7], + 2[y/4], - 3 + m - c + w + 7n) \quad \ldots\ldots (5)$$

where the name of the month should be substituted for M, except that one must be added for January and February of leap years.[9]

We shall now derive a formula much more convenient than the above for finding the calendar date for this and the next century and which could be modified for other centuries. Every 28 years the values of $4[y/7], + 2[y/4], - 3$ repeat themselves. From the year 1928 to 1956 they take the following values:

$$4321,6543,\ 8(1),\ 7(0),\ 65,3210,5432,2106$$

where 8(1) means $8 \equiv 1 \bmod 7$.

The first number and the number to the right of each comma represent leap years. They are in arithmetic progression and can be determined by $4 + 2[(y - 28)/4]_q = 2[(y - 20)/4]_q$. The numbers between commas are in arithmetic progression with -1 as common difference. Hence, any number in the series can be determined by

[8] This is easily proved from the relation $C = 4q + r$, $2C = 8q + 2r$. Hence, $2C \equiv q + 2r \bmod 7$, or $q = 2C - 2r \bmod 7$.

[9] The above formula for January, 1900, takes the form $4[y/7], + 2[y/4], \equiv 7 \bmod 7$. Starting with this observation it can be proved by mathematical induction that the formula holds for this and the next century.

the formula $2[(y-20)/4]_q - r$, where r is the remainder found when $(y-20)$ is divided by 4. Thus any future date can be found by the formula

$$\text{date} = 2[(y-20)/4]_q - r + m + w + 7n \quad \ldots\ldots\ldots \quad (6)$$

By omitting the last term, the formula will give the day of the month the day of the week falls on if y is less than 64. If this is not in the current week add or subtract a multiple of 7. For values of y greater than 63 either a multiple of 7 should be subtracted or 48 should be subtracted from y and later 76 should be subtracted. Since 112 is a multiple of 28 we can reason from that date and derive for the next century the formula—

$$\text{date} = 2[(y-4)/4]_q - r + m + w + 7n.$$

In formula (6) we observe that if $y = 20$ we get

$$d = w + m + 7n \quad \ldots\ldots\ldots\ldots \quad (7)$$

Hence, $2[(y-20)/4]_q - r$ is the correction to be applied for $y-20$ years. This can be checked by induction. If $y-20 = x+z$ where x is divisible by 4, the correction for $y-20$ = the correction for $x+$ the correction for z. If we let $x = 20$, $y-40 = z$. Hence correction for

$$y-20 = 10 + 2[(y-40)/4]_q - r \equiv -4 + 2[(y-40)/4]_q - r$$

(observe that in these methods b is the equivalent of a if $a-b$ is a multiple of 7).

We shall now derive a series for the month numbers by finding the negative of the values, $m-4$. The series so derived is

144, 025, 036, 146.

Letting m' be the month number determined from this series, we can now write another formula for finding the calendar date

$$d = w - m' + 2[(y-40)/4]_q - r \pm 7n$$

with the exceptions: 1 must be subtracted for January and February of leap years and $3[(C-20)/4]_q + r$ or its equivalent must be added for other centuries,— 1 for 2100, 2 for 2200, 3 for 2300, etc.

For other centuries, the method can be changed by methods we have pointed out. Thus since $10 \times 28 + 20 = 300$, a formula for $2200 + y$ is

$$d = w + m + 2 + 2[y/4]_q - r \pm 7$$

or

$$d = w - m' + 2 + 2[(y-20)/4]_q - r \pm 7n.$$

If the term $7n$ be omitted, the number found by the formula for this century will give one day of the month that will follow the day of the week with the exception that, for a few dates previous to 1956, 7 must be added to make the result positive and also with the exception that for a few dates after 1988, 7 must be subtracted. The largest number given by the formula is 35.

Anyone who has well in mind the formula and the series and who has some ability for the mental arithmetic of small numbers will in general be able to find the date in from ten to twenty seconds. Let us notice the mental process that makes it rapid. Suppose I be asked to find the dates of the Wednesdays of October, 1987. The abbreviation tells me to use 3 for w. I visualize the series and see that m' is 1. I see that I must divide 47 by 4 and that twice the quotient minus the remainder $=22-3=19$, and then I think $3-1+19$ is 21. The other possible dates are found by adding 7 and subtracting 7 and 14. For dates of the current year, it is easy to remember the correction. Thus, for 1940 it is zero; 1941, -1; 1942, -2; 1943, -3. These corrections are easily remembered by their relations to the year. It is Sat., Jan. 1941. What is the date? Jan.$(6-1-1)=$Jan. 4 or if it is near the last of the month Jan.$(21+4)$.

Rule: Subtract the month number from the week number and add the correction and then the least positive equivalent of the number found to one of the numbers, 0, 7, 14, 21, 28; the number used is determined by the approximate date. One must know the approximate date to find the date in a wall calendar.

Bloomington, Indiana.

PERPETUAL ECCLESIASTICAL CALENDARS

By C. E. White

THE purpose of the ecclesiastical calendar is to find the date of Easter and other movable feasts. Soon after the adoption of the Gregorian calendar the astronomers Lillus and Clavius constructed five tables for the determination of Easter.[1] The date of Easter given in almanacs and wall calendars is in general determined by these tables. No mental calendar is complete without a short method for finding the date of Easter. Gauss,[2] Zeller,[3] and Delambre[4] have derived formulas, but each is too complicated for mental computation. I discovered such a method in 1926 by observing that a simple relation existed between the "golden number" and the date of Paschal new moon, and an empirical derivation of the rule was published in *Popular Astronomy*, 1927. Later I observed that there was a simpler relation between the remainder found by dividing the year by 19 and the date of Paschal full moon as determined by the tables mentioned above, and in 1938 I found a mathematical proof of my method.

My last method stated as a rule is: Divide the year of the century by 19 for this century; and for other centuries divide the year by 19, multiply the remainder by 4 and, if the remainder be even, add 15 to the product and divide by 30. From the remainder so determined, if it be less than 21, subtract 1, except when the remainder found by dividing the year by 19 is 8 or 11. The number so derived, when more than 21, will be the date of Paschal full moon when it comes in March, and when less than 21, the date of Paschal full moon in April except when a division by 19 gives a remainder 5 or 16; in these latter two cases the date so determined

[1]This "very complicated and artificial though highly ingenious method" can be found in any edition of the *Encyclopedia Brit.* except the last.

[2]*Werke* de Gauss Vol. VI. I failed to find a copy of Vol. VI, but his formulas without derivation are given by Charles Leigh in *Nature*, Vol. 74; but the formulas given are inaccurate except for this and the next centuries.

[3]*Acta Mathematica*, Vol. 9, 1887. My method agrees with his for this and the next two centuries, and for other centuries if my computed date of Paschal full moon be increased by $C-[C/4]_q-[C/3]_q-9$.

[4]See article Calendar, *Encyc. Brit.*

is the date following Paschal full moon and if these dates fall on Sunday, that Sunday is Easter. In all other cases the Sunday following the date of Paschal full moon will be Easter. Find the date of the first Sunday of the month by one of the methods given in the present writer's article, "Perpetual and Mental Calendars"[5] and add a multiple of 7 to get a Sunday date just following the date of full moon.

Using the last method given in that article to find the calendar date, we observe that for Sundays in April $w=0$ or 7, and $m=0$; and the dates for Sundays are the correction $+7n$. Thus, to find the date of Easter for 1941,

$$d=4[41/19]_r-1=11. \quad \text{Also, } 2[(41-40)/4]_r-1=-1;$$
$$\text{and } -1+14=13.$$

Hence April 13 is the date of Easter. The correction $-4+7n$ will give the dates of Sundays in March. Thus, to find the date of Easter in 1959,

$$d=4[59/19]_r+15=23.$$

March $\{[2(59-40)/4]_q-3-4+28\}=$March 29, the date required.

A bracket with a "sub" r means that the remainder only is to be used; and a bracket with a "sub" q means that the integral part of the quotient is to be used.

The date of Easter for any year can be easily determined mentally.

The year 1900 was the beginning of a Metonic Cycle. Its golden number was 1 and its epact was 29. By epact we mean the age of the moon on January 1. According to tables III and IV of the ecclesiastical calendar, March full moon of that year fell on March 15, and the day after April full moon fell on April 15—a date that we use instead of the date of April full moon.

Since the length of the solar year is 365.25 days and the length of the lunar year is 354.375 days—an approximate difference of 11 days—the epact for 1901 was $(29+11-30)=10$. Since the epacts repeat themselves every 19 years, the epact for the nth year of the century will be (or was)

$$[(29+11m)/30]_r \text{ where } m=[n/19]_r.$$

If the epact, 29, be increased by $11m$, the time of April full moon

[5]Just preceding, in this issue.

and of March full moon will recede $11m$ days. Since $15-11m$ can be written $15-15m+4m$, the date of March full moon will be (or was)

$$\text{March } [(15-15m+4m)/30]_r,$$

and the date of the day following April full moon will be (or was)

$$\text{April } [(15-15m+4m)/30]_r.$$

When the remainder giving the date of March full moon is 1, March 31 should be used. In this particular case, two full moons fall in March. We observe that when m is even, these dates become March $[(15+4m)/30]_r$ and April $(15+4m)/30]_r$; and when m is odd, these dates become March $[4m/30]_r$ and April $[4m/30]_r$.

Now when $[(15+4m)/30]_r$ or $[4m/30]_r$ is greater than 21, the Paschal full moon is a March full moon and when either is less than 21 the April full moon is a Paschal full moon.

There are three corrections applicable to the above formulas. First, the difference between the solar and lunar years is not 11 days but $10\frac{7}{8}$ days, which recedes the epact 1/8 of a day as a correction each year, and advances the Paschal full moon 1/8 of a day each year, or one day in eight years. Second, since the 1/4 day in the solar and lunar years is not taken care of in the Calendar until leap year, the three years following would advance Paschal full moon, respectively, 1/4, 1/2 and 3/4 day. Third, the length of the synodic month is 29.5 days instead of 30 and this gives rise to a correction that is negative. To determine this last correction, we put $15-11m$ in the form $14\frac{3}{4}-14\frac{3}{4}m+1/4-m/4+4m$ and observe that

$$\text{March } [(14\tfrac{3}{4}-14\tfrac{3}{4}m+1/4-m/4+4m)/29.5]_r$$

and

$$\text{April } [(14\tfrac{3}{4}-14\tfrac{3}{4}m+1/4-m/4+4m)/29.5]_r$$

become when m is odd

March $[(1/4-m/4+4m)/29.5]_r$ and April $[1/4-m/4+4m)/29.5]_r$; and when m is even they become

March $[15-m/4+4m)/29.5]r$ and April $[(15-m/4+4m)/29.5]r$.

We observe that these formulas give 1 day less than the other formulas for $m=5$, 3 less for $m=16$ and $3\frac{1}{4}$ days less when $m=18$, but that the correction for other values of m is less than 1. The two positive corrections when added to the negative correction give a resultant less than 1 except for $m=16$ where the correction is -1. This explains only one of the four corrections that must be made to make the formulas agree with the tables.

The following table gives the date of the 14th day of the moon, Paschal full moon, as determined from the tables for each value of m of Paschal full moon for March and the date of the day after Paschal full moon for April as determined by the formulas for each value of m.

Values of m	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dates by table	14	3	23	11	31	18	8	28	17	5	25	14	2	22	10	30	17	7	27
Dates by formula	15	4	23	12	31	20	9	28	17	6	25	14	3	22	11	30	19	8	27

We observe that no correction is necessary for numbers greater than 21, for the March dates. Observing that in order to give the date following full moon, the numbers less than 21 in the third row should be one more than the corresponding number above. Hence, in order to make the computed dates agree with the others, it is necessary to subtract 1 when $m=5$ or 16 and add one when $m=8$ or 11, or observe that the April dates for $m=8$ or 11 are dates of full moon. An error of one day in either case would mean an error of one week in finding Easter in one year out of 131.

In table III of the ecclesiastical calendar, we find that for the same golden number—hence for the same value of m—the epacts for this and the next two centuries are the same. If y represents the year of the next century and if we let

$$m=[(100+y)/19],=[(5+y)/19],$$

the above formulas for finding the date of Paschal full moon will hold. In like manner, if we let $m=[(10+y)/19],$ the same formulas will hold for $2100+y$. For the next century, the date of the first Sunday in April of any year will be April $(8-b-6)$ and the date of the last Sunday in March will be March $(32-b-6)$. For the years $2100+y$, the date of the first Sunday in April will be April $(8-b-4)$ and for the last Sunday in March will be March $(32-b-4)$. In these formulas

$$b=[(y+y/4)/7],\equiv\{[y/4]_q-(7n-y)\} \bmod 7$$

where $7n$ is a multiple of 7 just greater than y.

For years having 22, 23, 24, 25 as century numbers, we divide the year and not y by 19 to find m, and increase the computed date for Paschal full moon by adding 1 for the years having 22 and 24 as century numbers and by 2 for the years of the other two centuries.

Let it be required to find the date of Easter for 1940. When

40 is divided by 19, we get a remainder, 2. Hence the date of Paschal full moon will be March $(4\times2+15)=$ March 23. In this case $b=10-(42-40)-7=1$.

The date of the last Sunday in March will be March $(32-1)=$ March $(8-1-4+28)=$ March 31, and the date of the preceding Sunday will be March 24 which, being the Sunday following March 23, will be the date of Easter.

Let it be required to find the date of Easter for 2142. When 2142 is divided by 19, we get 14 as remainder.

April $(14\times4+15-60)=$ April 11, the date of Paschal full moon. Here $b=10-7$, $c=6-2[21/4]_r$, April $(8-3-4+14)=$ April 15, the date of Easter.

The date of Easter can be determined by a formula that is a function of $(y-40)$. If S be the date of any Sunday in a month and if d be any other date, the date of the Sunday following the date d can be shown to be

$$d+\text{l.e.}(S-d) \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where l.e. means the least positive equivalent of

$$(S-d) \bmod 7=[(S-d)/7]_r,$$

except that, when the remainder is negative, 7 must be added. If d be the date of Paschal full moon in April or March the date of Easter would be

$$\text{April } (d+\text{l.e.}(S-d)) \text{ or March } (d+\text{l.e.}(S-d)) \ldots (2)$$

For March, when the remainder found by dividing y by 19 is odd, $d=4[y/19]_r$, and when the remainder is even, $d=[y/19]_r+15$. For this cycle

$$4[y/19]_r=4(y-2\cdot19)=4(y-40)+8$$

and $$4[y/19]+15=4(y-40)+23\equiv4(y-40)-7 \bmod 30.$$

For April when y is odd, $d=4(y-40)+7$, and when y is even, $d=4(y-40)-8$.

For April, $S=2[(y-40)/4]_q-r$,

and for March, $S=2[(y-40)/4]_q-r-4$.

For April, $(S-d)=2[(y-40)/4]_q-r-4(y-40)\pm7$

$$=2q-r-16q-4r\pm7.$$

Hence $$(S-d)=(-14q-5r\pm7)\equiv2r \bmod 7\equiv\text{l.e.}2[(y-40)/4]_r.$$

For March $\text{l.e.}(S-d)=\text{l.e.}\{[(y-40)/4]_r-4\}$.

Substituting in (2) we get—

$$\text{April } \{4(y-40)\pm 7+\text{l.e. } 2[(y-40)/4]_r\},$$
$$\text{March } \{4(y-40)\pm 7+\text{l.e.}(2[(y-40)/4]_r-4)\}.$$

The above formulas will give the date of Easter until 1947, but after 1946 it in general will be necessary to subtract 30 or a multiple of 30 to get a value of d that is less than 31. Since $30n\equiv 2n \bmod 7$, if $30n$ is subtracted from d, $2n$ should be added to $S-d$. The formulas were derived for this cycle of 19 years which begins one year earlier than the corresponding Metonic cycle. So, it will be necessary to derive the correction that must be applied for any other cycle. Letting m be the quotient when y is divided by 19, our problem is to find k, so that

$$4(y-2\cdot 19)-k\equiv 4(y-19m) \text{ or } \equiv 4(y-19m)\pm 15 \bmod 30.$$

Let y be odd and m odd, then we are to find k so that

$$4(y-2\cdot 19)-k\equiv 4(y-19m)+15 \bmod 30,$$
$$\text{or} \quad 4y-8\cdot 20+8-k\equiv(4y-80m+4m+15) \bmod 30,$$
$$\text{or} \quad -2-k\equiv 14m+15\equiv(15(m+1)-m) \bmod 30.$$

Hence, $k=m-2$. Any other assumption as to y and m gives the same value of k. We can find m for the cycle by dividing the multiple of 20 in the cycle by 20. Thus, for the next four cycles divide respectively 60, 80, 100, and 120 by 20. The beginning of each cycle respectively will be $60-m$, $80-m$, $100-m$ and $120-m$.

Inserting these corrections in the above formulas, we get

$$\text{April } \{4(y-40)\pm 7-30n-k+\text{l.e.}(2[(y-40)/4]_r+2n+k)\},$$
$$\text{March } \{4(y-40)\pm 7-30n-k+\text{l.e.}(2[(y-40)/4]_r-4+2n+k)\}.$$

When d is a Sunday date, Easter is the Sunday following. Hence where the true value of d is used, as when $+7$ is used in an April date and -7 in a March date when the value of l.e. is 0, it should be counted 7. When -7 is used in an April date d is the day following Paschal full moon, a 0 value of l.e. would be counted 0 except for $d=17$, when it should be counted 7. When $+7$ is used and $d=19$, a zero value of l.e. should be counted 0, and when $d=13$, if l.e. is 1, it should be counted 8.

Required to find the date of Easter for 1943,—

$$\text{April } \{4(y-40)+7+2[(y-40)/4]_r\}=\text{April } (12+7+6)=\text{April } 25.$$

Required to find the date of Easter for 1982. We observe that $k=4-2$, and

April $\{4\times42-7-150-2+1\text{i.e. }2[42/4],+10+2)\}$ = April 11.

To solve mentally, subtract 30 from 42 and observe that 4 thirties are subtracted.

In the above formulas, y is the year of the century number for this century. When the formulas are used in other centuries, y is the year minus 1900. Thus for 2040, $y=140$. When the formulas are used in other centuries except the next there should be a century correction.[6] It is likely that long before this is needed that the date of the second Sunday in April will be the date of Easter.

The Date of the Resurrection

The date of the crucifixion was March 25, 31 A.D., and the date of resurrection March 27, which can be proven as follows: The Julian Calendar began on the day of new moon following the winter solstice and the date of this day was January 1, 45 B.C. Paschal new moon came three months later, or on March 30, and Paschal full moon on April 12. A historical document, quoted in old commentaries and in the *Standard Dictionary of Facts*, and known as the Death Warrant of Christ, says: "In the year 17 of the Emperor, Tiberius Caesar, and the 25th day of March . . . Pontius Pilate, Governor of Lower Galilee, sitting on the presidential chair of the Praetory, condemned Jesus of Nazareth to die on the cross between two thieves . . ." According to scripture the crucifixion took place on the day he was sentenced.

Tiberius Caesar's reign was from 14 A.D. to 37 A.D. Hence He was crucified March 25, 31 A.D. Since there is no year zero B.C. or zero A.D., from 45 B.C. to 31 A.D. is a period of 75 years. From 45 B.C. to 32 A.D. is 76 years, a period known as the Callippic cycle. Hence Paschal full moon fell on April 12 in 32 A.D. This date, the second Sunday in April, had Easter been observed then as now, would have been the date of the first Easter. April full moon for 31 A.D. fell on April (12+11) = April 23, but this is too late for Paschal full moon. Hence, March 24 was Paschal full moon, and March 25 was the day of crucifixion.

[6] See article, "Perpetual and Mental Calendars," in this issue

The above furnishes argument in favour of making either the last Sunday in March or the second Sunday in April the fixed Sunday for Easter.

It is known that the year 1 A.D. came in on Saturday. Hence, January 2 was the date of the first Sunday, and the date of the first Sunday in April was April 5. Hence, the date of the first Sunday in April, 31 A.D., was April $(5-b)$. Since there was no year 0 to compute b, we let $n=30$, $b=7-(35-30)=2$, April $(5-b)$ =April 3. The date of the last Sunday in March is March 27, which, being the Sunday following the crucifixion was the day of resurrection. Hence, March 25 was on Friday—an observation that agrees with the New Testament. The document is given in an old concordance, but not found in recent ones because its authenticity is questioned.

The fact that the date in the document agrees with the astronomical dates and scripture tends to prove the authenticity of the document and makes it evident that in addition to the verbal sentence told in the Bible there was a written death warrant.

Bloomington, Ind.

THE VISUAL PHOTOMETRY OF VARIABLE STARS

By H. Boyd Brydon

(*Continued from page 162*)

Polarization by refraction. The structure of certain crystals, notably Iceland spar or calcite, is such that light passing through them in certain directions is plane polarized. The speed of light through the crystal varies with the direction in which it is passing. Put differently, the refractive indices of the crystal are different in different directions. In the calcite crystal (Fig. 14A), the refrac-

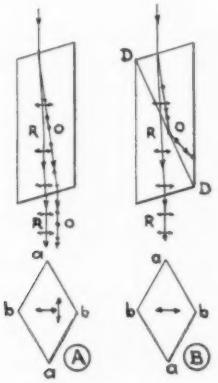


Fig. 14.—Polarization by Refraction.

tive index in the direction *aa* (see the plan), is 1·66 while along *bb* it is 1·49. In consequence, a beam of light entering the crystal is resolved into two beams of polarized light *O* and *R*.*

In most cases it is convenient to utilize only one of these beams, the other being turned aside. This is accomplished by causing it to be reflected. The calcite crystal is cut along the diagonal plane *DD* (Fig. 14B), the cut faces are then polished and cemented to-

*Perhaps the most concrete meaning of the "refractive index" of a substance is that it represents the ratio of the speed of light in air and in the substance.

gether again with Canada balsam which has a refractive index $\mu = 1{\cdot}53$. A crystal of calcite so treated is called a Nicol prism. It is possible to produce similar results by a like treatment of other substances.

When the ordinary ray *O*, for which in calcite $\mu = 1{\cdot}66$, strikes the less refractive balsam, for which $\mu = 1{\cdot}53$, it is totally reflected, as light seen from below the water-air surface is reflected in a tumbler of water, and is turned aside to be absorbed in the black varnish painted on the sides of the prism. But the extraordinary ray *R*, for which in calcite $\mu = 1{\cdot}49$, passes on through the prism unaffected, since for it the balsam is optically denser, and emerges from the prism vibrating in the direction *bb* shown in the plan.

If now an analyser consisting of a second Nicol be placed symmetrically below the first the Nicols are said to be parallel and the extraordinary ray will pass unaltered through the second Nicol also. But when the analyser is rotated the intensity of the polarized ray will be reduced in proportion to $\cos^2\alpha$, α being the angle turned through from the position where the intensity of the issuing ray is a maximum, i.e., that where the Nicols are parallel.

A moment's consideration will make it clear that as the analyser is turned through a complete circle there will be four positions where the light will have the same intensity: α, $180-\alpha$, $180+\alpha$ and $360-\alpha$.

To eliminate any errors due to improper fitting of the Nicols, eccentricity of the circles or in reading the angles, it is usual to read all four of these positions and to compute the difference of magnitude from the average.

This means of light-modification is capable of very accurate results, but the great loss of light involved, about 60 per cent., limits its usefulness to telescopes of fairly large aperture.

Turning now to the photometric methods themselves, the first listed, that of extinguishing the star, for which a wedge was used by Prof. Pritchard in the work above mentioned, has been severely criticized, notably by E. C. Pickering, who remarks[54] that estimates made by this method on different nights or by different observers varied by as much as three magnitudes and concludes "it cannot give the accuracy attained in the direct comparison of two stars."

[54] *H.A.*, v. 11, p. 180.

Undoubtedly varying atmospheric conditions, the presence or absence of moonlight, etc., will affect the actual wedge readings, but it is difficult to follow this sweeping condemnation. A sufficient answer would seem to be that the method proved highly successful at the hands of Pritchard and his assistants. Indeed these objections were directly countered by him by the publication[55] of a series of observations which showed satisfactory agreement. Further, as the observations are purely relative, so long as the same wedge scale difference obtains between the same two stars it is immaterial whether it occurs at one part of the wedge or at another. Inevitably the position on the wedge will change as the conditions of observation change, not merely from night to night but from hour to hour. In Prof. Pritchard's work, for instance, it was found desirable to observe the comparison star at the beginning, in the middle and at the end of each set of observations. Further, all observations were corrected for the increase of atmospheric absorption with the increasing zenith distances of the stars.

Another objection which applies to all like observations is the extreme difficulty and eye-strain in the attempt to determine the point of vanishing of a star which is just disappearing or has just disappeared but, owing to an involuntary movement of the eye, may reappear should its image fall upon a more sensitive part of the retina. R. L. Waterfield[56] has suggested the use of an auxiliary point of light, a sort of aiming point, upon which the fovea may be fixed while the fading of the star to disappearance is observed by a peripheral part of the retina.

It would seem preferable to fix the stellar image itself on the fovea by looking steadily at the star. The point of extinguishment would then be determined in a manner similar to that used in focussing a glass; by moving the wedge back and forth across the point where the star disappears and reappears and accepting as the point of extinguishment the middle of this swing.

The suggestion, however, once more emphasizes the importance, stressed by many observers, of forming the habit of looking consciously, directly and fixedly at the star, thereby avoiding the not

[55] *M.N.*, v. 42, p. 224.
[56] *J.B.A.A.*, v. 36, p. 260.

uncommon fault of, in effect, looking past it, especially when other stars are in the field.

The second method is the direct comparison of one star with another in the same field by equalizing their brightnesses. When a wedge is used

$$\Delta m = KR,$$

where K is the wedge constant and R the reading of the scale when the two stars appear equally bright.

The usual procedure is as follows: The variable and the selected comparison star are placed equidistant from the centre of the field and between the parallel wires set in the focal plane of the eyepiece. The photometer is then turned in the focussing tube until the wedge is at right angles to the line joining the two stars and covers that

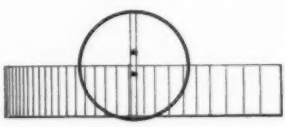


Fig. 15.—Arrangement of Stars and Wedge in Field.

half of the field containing the brighter of them (Fig. 15). The wedge is then adjusted until the stars appear equally bright and the scale reading is noted. At least three settings should be made with each comparison star and it is a good plan to effect the equalization by opposite motions of the wedge, increasing and decreasing respectively the brightness of the comparison star. The process is repeated with the other comparison stars. All observations should then be repeated with the positions of the stars reversed in the field, to eliminate position angle error. Finally, the apparent magnitude of the variable is computed from each comparison by the relation

$$M_v = M_c + KR,$$

the average of the results being accepted as the correct value.

A simple photometer of this type, due to W. S. Houston, is shown in Fig. 16. The wedge W is secured to a strip of hardwood P which slides smoothly between the front and back aluminium plates F and B which form the body of the photometer. A key-way K' is

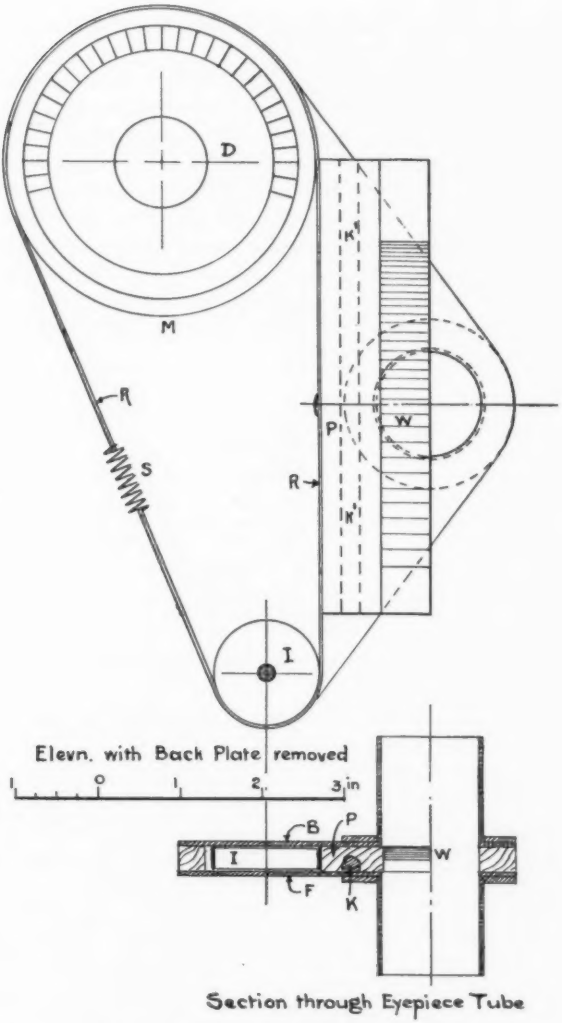


Fig. 16.—Houston's Wedge Photometer.

cut in P in which a feather key K fits and maintains the movement of the wedge in correct direction.

In this design the wedge is moved by a flexible ribbon R of copper-vanadium alloy screwed to the centre of the wedge carrier P and passing round the idler pulley I and the main pulley M, the ends being connected by a strong spring S which maintains the tautness of the belt and prevents backlash. Creep of the belt is prevented by screwing it to a suitable point on the main pulley. The belt drive used is preferred to the usual rack and pinion device and to a simple push and pull of the wedge, as it is believed to be freer from the possibility of the wedge being set by feel, thereby eliminating a possible psychological error. The position of the

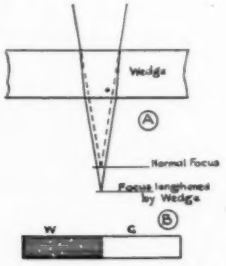


Fig. 17.—Lengthened Focus due to Wedge and Method of Equalization.

wedge is read from a large radio dial D secured to the main pulley, tenths of a division being estimated.

When a wedge is used in this manner the focus in the wedge half of the field is lengthened by about one-third the thickness of the wedge and both stars cannot be brought to a sharp focus at the same time. Since the brightness of a stellar image varies inversely as the square of its extra-focal distance, this condition may cause appreciable error in estimating the comparative brightness of two stars. The difficulty which is due to refraction, as in indicated in a greatly exaggerated way in Fig. 17A, can be relieved by the use of a slip of plate glass G of the same thickness as the wedge W, fitting against its exposed edge and covering the other half of the field, Fig. 17B.

A direct-comparison polarizing photometer is shown in Fig. 18. It is Pickering's photometer "H" and was used with the 5-inch and 15-inch telescopes at Harvard College Observatory.[57]

In this instrument the polarized double images of the two stars are formed by the Rochon prism *P* which slides in the tube *T* fitting into the focussing tube of the telescope. By sliding the prism along the tube by the cord *C* to the proper distance from the focus, these images can be brought close together for comparison whatever may be the actual separation of the stars in the field. The images are equalized by rotating the eyepiece tube *E* which carries round with it the analysing Nicol *N* and the graduated circle *G*. The indices, *D*, *D*, being supported from the tube *T* are stationary. This arrangement facilitates reading the circle as the reading points remain in one position.

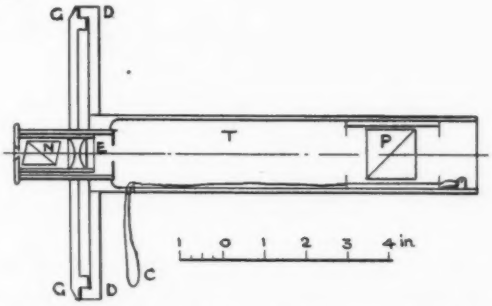


Fig. 18.—Pickering's Polarizing Photometer "H".

Two disadvantages of the method of direct-comparison must be mentioned. The first is the difficulty of finding completely satisfactory comparison stars within the restricted field of the eyepiece, limited further by the necessity, or at least the great desirability, that both stars be close to its centre; and, second, the necessity of taking double sets of readings in order to eliminate by reversal errors due to the relative position of the stars, which affect all estimations of the relative brightness of two stars in the same field and may amount to several tenths of a magnitude.

[57] *H.A.*, v. 11, p. 4. This volume contains scale drawings and discussions of several photometers developed at Harvard.

In the third method the two stars are compared by noting the difference in brightness of an artificial star when it is made equally bright with each in turn. This method is free from the three objections stated above; great loss of light, small field of view, danger of position angle errors, but it has been criticised by Pickering on two counts. First, as the real star is intrinsically brighter and is continually varying or twinkling it is difficult to compare it with the larger, paler, steadier artificial star; second, changes in the opacity of the air affect only the real star. The second is perhaps the more serious, especially in fundamental determinations of stellar magni-

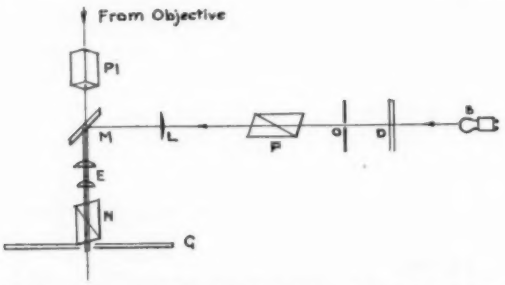


Fig. 19.—Optical System of Shook's Polarizing Artificial Star Photometer.

tude which was Pickering's object at the time, but the vast amount of stellar photometry, both fundamental and relative, successfully accomplished by this method seems a sufficient answer to both counts. None the less, the importance of imitating the appearance of the real star with the artificial one should be kept in mind.

The conspicuous examples of this type of photometer are the Zöllner, which uses polarization, and the Rumford which uses a wedge to vary the light of the artificial star. Many descriptions of these photometers have been published[58] and will not be given here. Instead, certain instruments of similar but simpler construction will be described.

[58]E.g., "Enc. Brit.", art. Photometry; BELL, "The Telescope"; FURNESS, "Introduction to the Study of Variable Stars," etc.

[59]For details of this instrument see "Design of a Stellar Photometer," *Pop. Ast.*, v. 28, p. 595, also BELL, "The Telescope," p. 197.

The optical system of a photometer of the Zöllner type due to Dr. G. A. Shook is shown in Fig. 19.[59]

Light from the real star passes from the objective, through the unsilvered plane-parallel glass diagonal mirror M (which may be a piece of microscope slide) and forms a real image in the focal plane. The artificial star is formed at the small orifice O by light from the flash light bulb B passing through the ground glass diffuser D. Its light is then polarized by the Nicol P and reflected from both faces of the mirror M to the focal plane where, by adjusting the focussing lens L, two images of it are formed, one on each side of the real star image in the centre of the field.

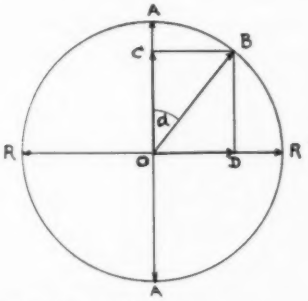


Fig. 20.—Shook Polarizing Artificial Star Photometer Effect of rotating Analyser.

The polarizer P is set so that the polarized light vibrates parallel to the plane of the mirror M. In practice, the fainter image of the artificial star, that from the far surface of the mirror, is not infrequently neglected in making the measurements and the equalization of brightness made with the brighter image only.

The eyepiece E is fitted with an analysing Nicol N, and the graduated circle G. The indices are arranged as in Pickering's Photometer H, Fig. 18.

In another form of the instrument an additional polarizer (P_1) is placed in the path of the rays from the real star so that the polarized light vibrates at right angles to that from the artificial star. The effective range of comparison is increased by this addition, as rota-

tion of the analyser N now varies the light of the real star as well as that of the artificial star, the one increasing while the other decreases.

It is of interest to compare the performance of the photometer with and without the additional polarizer.

Let Fig. 20 be a plan of the focal plane in which AA represents the direction of vibration of the polarized light from the artificial star, and RR, perpendicular to AA, that from the real star. Then as the analyzer N is rotated, OB will represent at some instant, in direction and amplitude, the vibration resulting from the combination of the two, and at any angle α, less than 90° in the figure, the amplitudes of the respective vibrations will be

$$OB \cos \alpha = OC, \text{ and } OB \sin \alpha = OD.$$

As the intensity varies as the square of the amplitude the corresponding intensities will be:

$$I_A \cos^2 \alpha \text{ and } I_R \sin^2 \alpha,$$

whence $I_R/I_A = \cot^2 \alpha = 2{\cdot}512^{\Delta m}$, ... (1)

and $\Delta m = 5 \log \cot \alpha$.

Then if the intensities of two stars v and c compared with that of the artificial star be, respectively,

$$I_v = I_A \cot^2 \alpha_1 \text{ and } I_c = I_A \cot^2 \alpha_2,$$

we have $$I_v/I_c = \cot^2 \alpha_1 / \cot^2 \alpha_2 = 2{\cdot}512^{\Delta m}$$

whence $\Delta m = 5 (\log \cot \alpha_1 - \log \cot \alpha_2)$.

When one polarizer only is used the artificial star alone is varied by the rotation of the analyser and we have

$$I_v = I_A \cos^2 \alpha_1 \text{ and } I_1 = I_A \cos^2 \alpha_2 \ldots\ldots\ldots\ldots\ldots (2)$$

whence $I_v/I_c = \cos^2 \alpha_1 / \cos^2 \alpha_2 = 2{\cdot}512^{\Delta m}$,

and $\Delta m = 5 (\log \cos \alpha_1 - \log \cos \alpha_2)$.

To indicate the performance of the photometer in the two cases, we compare the values of the angle α through which the analyser must be turned to reduce the (constant) brightness of the artificial star to equality with stars of magnitudes one to five respectively. It is convenient to invert the equations (1) and (2) and when the two polarizers are used, we have

$$I_v = I_A \cot^2 \alpha,$$

whence $I_A/I_v = \tan^2 \alpha$ and $\Delta m = 5 \log \tan \alpha$.

Similarly, when one polarizer only is used we have $I_v = I_A \cos^2 \alpha$, whence $I_A/I_v = \sec^2 \alpha$ and $\Delta m = 5 \log \sec \alpha$.

In the first case as the use of the second polarizer allows the magnitude of the real star to be greater or less than that of the artificial star, let the magnitude of the artificial star = 3·0.

Where but one polarizer is used, the artificial star must be $\gtrless$ the real star: let its magnitude be 1·0. Then, putting $\Delta m = 0, 1, 2, 3$, etc., the corresponding values of the angle α can be computed. These values appear in Table IX.

TABLE IX. Comparison of artificial star photometers having one and two polarizers

Magnitude of variable	One polarizer		Two polarizers	
	Δ m	α deg.	Δ m	α deg.
1	0	0	−2	21.7
2	1	50.9	−1	32.2
3	2	66.5	0	45.0
4	3	75.5	+1	57.8
5	4	80.9	2	68.3
6	5	84.3	3	75.9

These relationships are shown graphically in Fig. 21 where curves *A* and *B* compare the one and the two polarizer forms for the magnitude differences given in the table. Curve *C* shows on an enlarged scale the lower part of curve *A*.

Considering the five-magnitude range of Table IX and curve *B*, the advantage undoubtedly is with the two-polarizer form as the more regular angular differences over this range show.

But when the difference is not much greater than 1·5 mag., curve *A* shows it to lie with the single-polarizer form; first, because of the greater angular differences for these smaller magnitude differences; and, second, because of its simpler construction and freedom from the loss of light from the real star amounting to some sixty per cent. which is involved in the use of the second polarizer.

Wide range in such a photometer as this is of no particular advantage. But the ability to reduce the brightness of the real star is of value as in general it is easier to estimate correctly the

relative brightness of moderately bright than of very bright stars. This desirable feature could, however, be had more easily by the use of a neutral-tinted shade-glass which could be used to dim the light of either the real or the artificial star as occasion demanded.

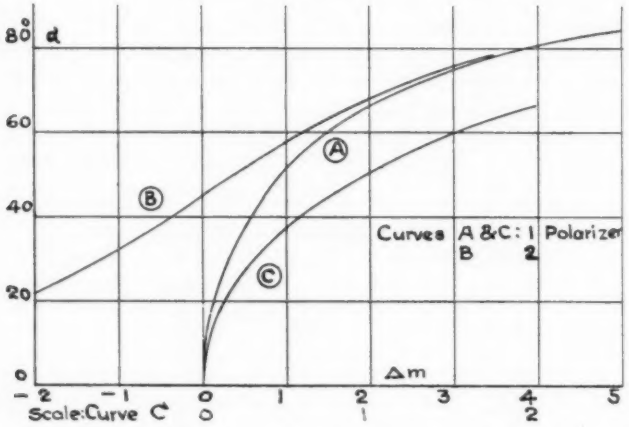


Fig. 21.—Relative Performance of Polarizing Artificial Star Photometer having one or two Polarizers.

An artificial star photometer of the Rumford type is much simpler than the Zöllner instrument. No prisms nor graduated circles are required, simply a wedge is inserted in the path of the light from the artificial star as at *W* in Fig. 22. There is no loss of light from the real star except that due to absorption in the lenses or mirrors of the telescope itself which are common to all methods of photometry.

The image *r* of the real star is brought to the centre of the field in close juxtaposition with the images of the artificial star *aa*. The brightness of the artificial image is made equal to the image of the real star by adjusting the wedge *W*, and the wedge scale read.

If R_v be the wedge reading with the variable star and R_c that with the comparison star, we have

$$\Delta m = K\,(R_v - R_c).$$

An even simpler artificial star photometer of the wedge type is Steavenson's "Glass Plate" photometer illustrated in Fig. 23.[60] In designing this instrument it was sought to obtain an artificial star which would meet the objections of Pickering and others and look

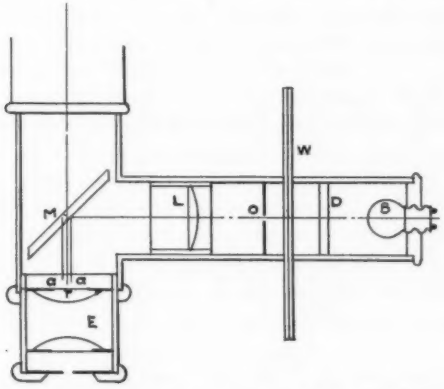


Fig. 22.—Rumford or Wedge Type Artificial Star Photometer.

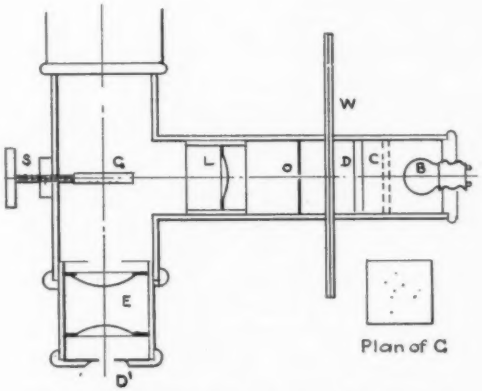


Fig. 23.—Steavenson's "Glass Plate" Photometer.

[60]W. H. Steavenson, "A Simple Stellar Photometer," *M.N.*, v. 92, p. 839.

more like a real star than does an orifice and to avoid the loss of light due to the use of a reflector placed in the cone of rays from the real star.

The principle is that used in advertising signs in which the letters shine in a sheet of plate glass lighted from below through one edge.

Light from the small electric bulb *B*, made nearly parallel by the achromatic condensing lens *L*, shines through one edge of a piece of plate glass *G* about $\frac{3}{4}$-inch square and 0·1-inch thick set in the focal plane of the telescope, and illuminates a number of minute pits made in the surface facing the eyepiece. To absorb unwanted reflections the other edges and a narrow border round the faces of the plate are coated with black varnish.

Depending upon the way the light strikes them, these artificial stars appear of different magnitudes. The glass plate is therefore made movable by the screw *S*, to allow a selection to be made.

In the telescope the illuminated pits shining in the dark field are said to resemble real stars more closely than does the usual illuminated orifice.

Provision is made at *C* for the insertion of coloured filters if desired. The wedge *W* used is about 3 inches long and has a transmission of about $100-1$.

Certain points mentioned by Dr. Steavenson in the manipulation of this photometer might be adopted with other instruments. "The star to be measured is brought close beside the artificial star in the field of view. The light is then adjusted either by a rheostat or by altering the focus of the condenser *L* until the artificial star appears about as bright as the real one. Then the wedge is adjusted until both objects appear of sensibly equal brightness." When the observation is recorded the telescope is set on the comparison star, usually selected from the North Polar sequence, and the wedge (only) adjusted until the same artificial star appears equally bright.

The observations are recorded, not by reading a wedge scale, but by marking with a sharply pointed pencil a card held against the fitting carrying the wedge. This is done in darkness to preserve the sensitiveness of the eye. A separate card is used for each measure or pair of measures and the positions of the marks and their separations read and reduced later.

The manufacturing difficulty in this photometer appears to be

in making small enough pits in the glass plate. The operating difficulty lies in maintaining a definite line of sight through the eyepiece to the pair of stars. Dr. Steavenson remarks, "As the cone of rays entering the eyepiece from the artificial star is far from being of uniform intensity it is important that the emergent pencil of rays should be kept smaller than the pupil of the eye by means of a diaphragm (D^1) over the eye lens. With high powers its diameter should be about equal to the Ramsden disc."

Double cross-hairs in the eyepiece should be useful here.

The photometer is said to work well and to be easy to use and that in its first trial ten pairs of settings on two stars differing by about half a magnitude had an average deviation of 0·048 mag. and a maximum of 0·07 mag. The wedge, of course, must be accurately calibrated.

The principle underlying the use of extra-focal images in stellar photometry is: "the illumination L of a surface varies inversely as the square of its distance D from the (point) source of light" or

$$L_1/L_2 = D_2^2/D_1^2.$$

Some illustrations of the working of this law may be given:

1. If two lights illumine a surface equally when one, A, is twice as far from it as the other, B, then A is four times as bright as B.

2. If a given surface is illuminated by a light at a distance D, then at a distance $2D$ the area of the surface illuminated will be four times as large.

3. Under good seeing conditions the image of a star at the focus of a telescope is practically a point. Extra-focal images, however, are illuminated areas. If the extra-focal images of two stars are equally bright when their extra-focal distances are as 1 to 2, the brightness of the two stars is as 1 to 4. This principle is utilized in a photometer due to Mentore Maggini.[61]

In this instrument (Fig. 24) the image of the artificial star formed by the small orifice O is focussed by the lens L on an aluminized or silvered spot a, formed on the diagonal clear glass mirror M and about the same diameter as the orifice. The image of the variable star is focussed sharply and the reading of the scale S engraved on the focussing tube of the telescope is noted, giving the zero of dis-

[61] "A New Stellar Photometer," *Pop. Ast.*, v. 26, p. 380.

tance. The focussing tube is then moved outwards a measured distance D_v and the extra-focal image of the variable caused to surround the artificial star image. The brightness of the artificial star is then adjusted by means of a wedge, as at W, or by movement of the light bulb, or by a rheostat, or by other means, until it is

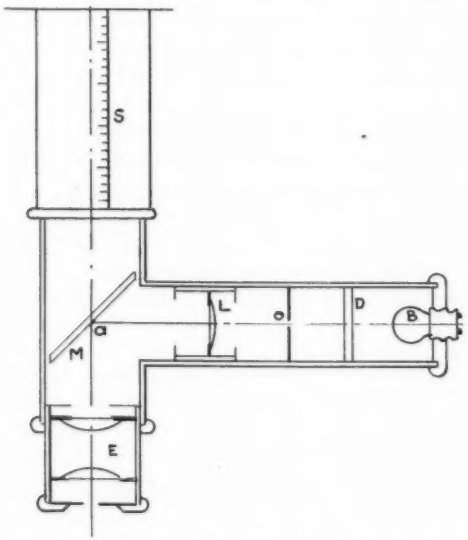


Fig. 24.—Maggini's Extra-Focal Artificial Star Photometer.

equal to and consequently disappears in the extra-focal image of the variable. The telescope is now directed upon the comparison star and, without altering the brightness of the artificial star, the focussing tube is again moved a measured distance D_c until the artificial star once more disappears, this time in the extra-focal image of the comparison star.

Then, as the intensity of the light is proportional to the square of the extra focal distance, the ratio of the brightness of the two stars I_v and I_c is

$$I_v/I_c = D_c^2/D_v^2 = 2{\cdot}512^{\Delta m},$$

whence $\Delta m = 5(\log D_c - \log D_v)$.

With this instrument, the position of the wedge being unchanged during a comparison, calibration is unnecessary; the difficulty of measuring accurately the diameters of extra-focal images is avoided and the images of both stars, being in the centre of the field, are free from position angle error.

On the other hand, as this photometer is subject to the loss of light common to all extra-focal methods it is unsuited to the photometry of stars close to the visual limit of the telescope. Further, there is some question as to the extent to which the image of the artificial star can be made to merge into the extra-focal images of the real stars should these differ appreciably in colour. However, as by a suitable filter the colour of the artificial star can be made to lie between the colours of the stellar images, error from this source should be less than might occur in direct comparisons of the stars.

Following Steavenson's method mentioned above, the several measurements can be recorded by marking the distances on cards held against the focussing tube or by any of several other possible methods which may prove more satisfactory than reading a scale engraved on the focussing tube.

When a photometer is used with a refractor, the fact that the focal-length of an achromatic objective is not the same for light of all wave-lengths may affect the results. Between the *C* line in the red, λ6563, and D_1 in the yellow λ5896, for instance, the difference may amount to 6 to 8 thousandths of the focal length or perhaps more. Thus as Bell remarks:[62] "The differences concerned in this chromatic correction for power (magnification) are by no means negligible in observing."

When the colours of the stars are appreciably different then it is important to determine for each the point at which it is sharply in focus, from which as zero the extra-focal distance is to be measured. It is possible that the accuracy of direct comparison methods also may be affected by this cause which is absent when a reflector is used.

Atmospheric Absorption. The use of an artificial comparison star as an intermediary frees the observer from the restrictions encompassing direct-comparison methods and errors due to position

[62] "The Telescope," chap. IV, p. 91.

angle, for the image of the real star may be placed on any side of the artificial star image by a slight movement of the telescope. The effect of varying atmospheric absorption, however, must be taken into account.

As given in modern catalogues, the magnitude of a star is that which it would have were it situated in the zenith. Magnitude estimates made at lower altitudes therefore must be corrected for the correspondingly greater absorption due to the greater thickness of the atmosphere traversed by the light. The correction is applied automatically when the stars are close together as in direct com-

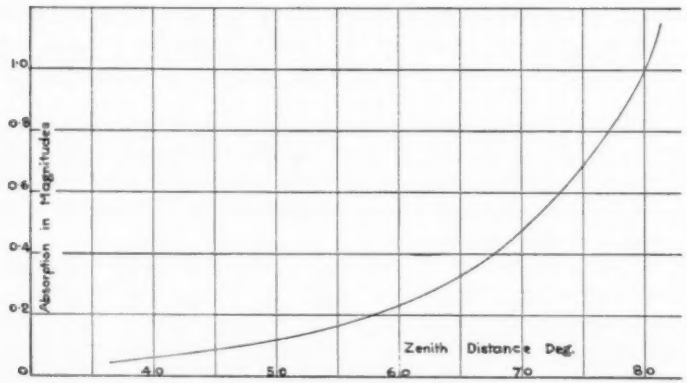


Fig. 25.—Approximate Increase in Atmospheric Absorption with Increasing Zenith Distance.

parisons but when they are farther apart, especially in altitude, the appropriate correction must be applied to the magnitudes as observed. Local haze and smoke also must be considered.

The value of the correction can be determined rapidly with a photometer by comparing the apparent brightness of two stars situated one in the neighbourhood of the star under observation and the other near the zenith whose magnitudes are accurately known.

When a photometer is not available one of the general formulae for atmospheric absorption must be used. A number have been

devised, most of which apply satisfactorily until the zenith distance becomes large. That commonly used is of the form

$$m - m_0 = a \sec Z,$$

where m is the magnitude of the star as observed, m_0 the magnitude it would have if in the zenith, Z the zenith distance in degrees, and a, a constant. For zenith distances less than 40° the increased absorption is less than 0·1 mag. but, as shown by the curve in Fig. 25, becomes rapidly greater as the distance increases, although beyond a zenith distance of 65° the curve is unreliable. Up to that point, however, it affords an approximate value for the correction which is useful in the case of bright stars for which suitable comparison stars are few and far between. The zenith distances can be measured with sufficient accuracy with any simple altimeter such as a semi-circular protractor having a short plumb line suspended from its centre. It is not advisable to rely upon unaided eye estimates of altitude as these generally make all zenith distances too small.

In addition to those to whom my acknowledgements and thanks already have been offered, I am grateful to many others who have aided me in the preparation of this portion of the paper: to Dr. D. B. McLaughlin for permission to use material from his paper on Novae; to Dr. W. H. Steavenson, F.R.A.S., for permission to quote from his paper on the glass-plate photometer; to Mr. D. W. Rosebrugh, the present Secretary of the A.A.V.S.O.; to Dr. G. A. Shook and to Mr. W. S. Houston, designers of the photometers described and for details regarding direct comparison methods. The prompt and cordial manner in which this assistance has been given has been most valuable.

Victoria, B.C.

IMPROVED TELESCOPE SPIDER DESIGN

By C. H. Werenskiold

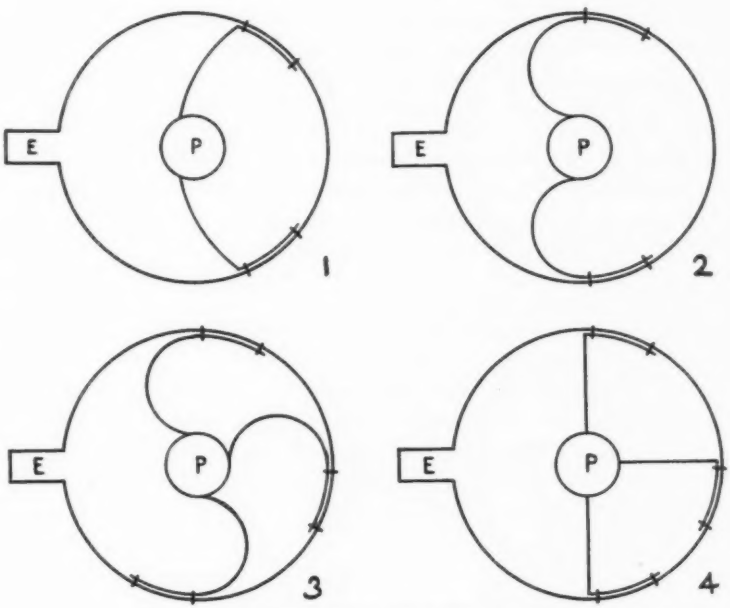
AN interesting method of eliminating the spikes or cross-lines in the images of prominent stars when viewed or photographed with a reflecting telescope has been described by A. Couder in *L'Astronomie*, January 1934. A translation of his article appears in "Amateur Telescope Making, Advanced" (Scientific American Publishing Co.), pages 620-622. This method consists in placing, in the open end of the telescope, a diaphragm having four elliptical openings, in such a manner as to cover or hide the four straight arms of the spider and in effect provide them with a curved outline. A modified procedure is also described in which the spider arms are covered with small plates or screens of curved outline. The spikes or cross-bars in the star images were eliminated in both cases.

The use of diaphragms or screens naturally causes a certain loss of light, and it has occurred to the writer that this loss can be reduced to a minimum by curving the spider arms themselves, which would render the use of diaphragms or screens unnecessary.

Several methods for accomplishing this are possible, of course, such as suggested in Figs. 1-3, where *E* indicates the position of the eye-piece, and *P* that of the assembly supporting the prism or diagonal.

Up to recently the writer has employed the "straight" spider construction of Fig. 4, made from brass strip approximately 1 inch x 1/16 inch, in an 8½-inch reflector, and no substantial mechanical weakness or vibration due to the omission of the fourth spider arm has been noted. The star images with this spider naturally exhibited the usual spikes. In considering the various possible "curved" spider designs, the one shown in Fig. 1 appeared most attractive from a mechanical standpoint, since its arch-like design offered strength and stability, together with a reduction of the number of spider arms to two. A curved spider of this type, made from brass strip approximately 1 inch x 3/32 inch, was substituted for the straight spider formerly employed and has been found both mechanically satisfactory and effective in eliminating the spikes from the star images.

Furthermore, the definition obtained in the observation of planets, such as Jupiter and Saturn, appeared to be considerably improved. This is readily understood when we consider that the bright disc of a planet as seen in a telescope constitutes a pattern composed of smaller light elements. Each of these, depending on its individual



Figs. 1 to 4. Four designs for telescope "spiders".

brightness, gives rise to more or less luminous cross-lines or spikes when a straight spider is employed, with the total result that the image of the planet is accompanied by a hazy, more or less noticeable, cross-band of light, approximately as wide as the diameter of the planet and oriented in the manner of the usual star spikes. It seems obvious that the definition would suffer under such circumstances, the fine detail originally rendered by the mirror being again partly obliterated by the superimposed cross-band of light. Since no such

cross-band is formed when a curved spider is used, the definition is improved accordingly.

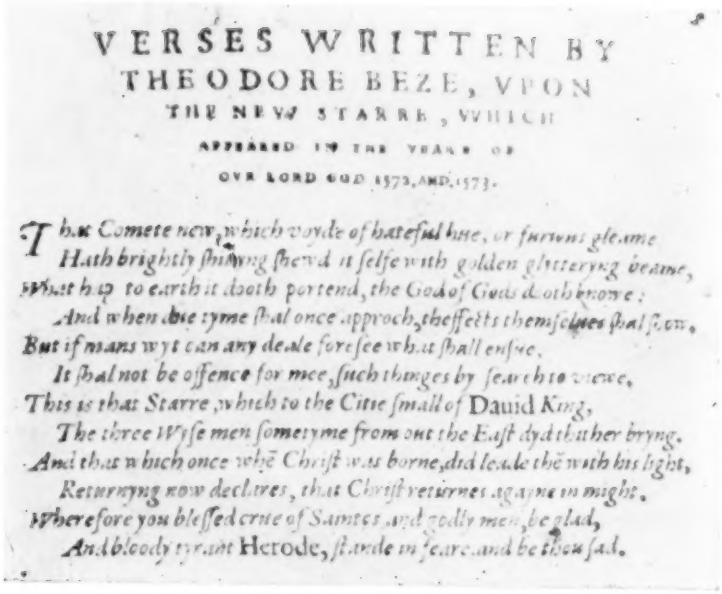
As to the practical construction of the spider of Fig. 1, it was found desirable to prepare an exact drawing beforehand and to calculate geometrically the overall length of the spider to determine the exact position of the bends adjoining the telescope tube. In order to obtain satisfactory results, one must make certain that each spider arm is curved continuously without any straight sections. As the work progresses, the shape of the spider should therefore be compared carefully with the drawing. A liberal additional length of strip was allowed for fastening the spider to the telescope tube with short bolts. The holes for the bolts were elongated lengthwise of the strip, and the corresponding holes in the tube were elongated at right angles to this, i.e., lengthwise of the tube, to the extent required for adjusting the spider to its correct position.

The more strongly curved forms shown in Figs. 2 and 3 may have certain advantages in construction, such as lessened danger of straight sections, but whether these modifications are otherwise practical has not been investigated.

It is generally conceded that a reflector, in regard to definition obtained, is apt to be somewhat inferior to a refractor of comparable size. However, the use of a curved spider in a reflector appears to be a promising step towards reducing this difference in comparative performance of the two types of telescope.

New York, N.Y.

PLATE XI



VERSES WRITTEN BY
THEODORE BEZE, VPON
THE NEVV STARRE, WHICH
APPEARED IN THE YEARE OF
OVR LORD GOD 1572. AND. 1573.

That Comete new, which vvonde of hateful hue, or furious gleame
Hath brightly shining shevvd it selfe with golden glittering beame,
What hap to earth it doeth portend, the God of Gods doth knowe:
And when the tyme shal once approch, the effects themselues shal showe.
But if mans wyt can any deale foresee what shall ensue,
It shal not be offence for mee, such thinges by search to vievve.
This is that Starre, which to the Citie small of Dauid *King,*
The three Wyse men sometyme from out the East dyd thither bryng.
And that which once whē Christ was borne, did leade thē with his light,
Returnyng now declares, that Christ returnes againe in might.
Wherefore you blessed crue of Saintes and godly men, be glad,
And bloody tyrant Herode, *stande in feare, and be thou sad.*

VERSES ON TYCHO'S NEW STAR 1572
FROM AN OLD BOOK PRINTED IN 1578

Journal of the Royal Astronomical Society of Canada, 1941.

AN EARLY REFERENCE TO AN ASTRONOMICAL EVENT COMES TO LIGHT

By W. Kenneth Angus

(With Plate XI)

THE sixteenth century poem reproduced in the accompanying plate was discovered by the writer when examining an ancient volume of sermons. There is very little doubt that it refers to the great nova mentioned by Tycho Brahe as appearing suddenly in the year 1572, and it is also very likely that this is the only copy of the poem in existence.

It reads as follows, with two slight alterations in the ninth line, two words having been abbreviated by the printer in order to get all the words into a single line:—

That Comete new, which voyde of hateful hue, or furious gleame,
Hath brightly shinyng shewd it selfe with golden glytteryng beame,
What hap to earth it dooth portend, the God of Gods dooth knowe:
And when due tyme shal once approch, the effects themselves shal show.
But if mans wyt can any deale foresee what shall ensue,
It shal not be offence for mee, such thinges by search to viewe.
This is that Starre, which to the Citie small of David King,
The three Wyse men sometyme from out the East dyd thither bryng.
And that which once whe[n] Christ was borne, did leade the[m] with his light,
Returnyng now declares, that Christ returnes agayne in might.
Wherefore you blessed crue of Saintes, and godly men, be glad,
And bloody tyrant Herode, stande in feare, and be thou sad.

The poem appears on the reverse side of the title page of a book which is entitled "*Of the ende of this worlde, and seconde commynge of Christe, a comfortable and moste necessarie discourse, for these miserable and daungerous dayes.*" and the printer's footnote reads, "*Imprinted at London, nigh unto the Three Cranes in the Vintree, for Andrew Maunsel, dwellyng in Paules churchyarde, at the Signe of the Parret, Anno Domini, 1578.*" The book is one of several bound together in one volume, the whole forming to-day, needless to say, a truly precious museum piece.[1]

[1]It is now in the possession of Mr. F. G. A. Makepeace, chief engineer, radio station CFRN, Edmonton.

One has to hark back to the days before the coming of the Spanish Armada, to the days of Queen Elizabeth and Sir Francis Drake, Shakespeare and Tycho Brahe, to find the proper setting for these verses, which were written very soon after the astronomical event that inspired their now forgotten author. Most general texts on astronomy carry accounts of the 1572 nova, as do many of the histories of early astronomers. The following paragraph is from a now outdated work by Thomas Milner,[2] but his account of Tycho's discovery is probably as interesting as any:—

"In the year 1572, the remarkable event of a stellar apparition attracted the attention of Europe, and excited universal speculation. It was early in November, when Tycho observed a star of great splendor in the constellation Cassiopeia, which he had never seen before, as he was walking across the fields about ten o'clock in the evening. It beamed with a lustre quite unwonted in that part of the heavens. It could not have escaped his observation had it previously been there. He suspected at first an optical illusion, but found a group of peasants gazing upon it with as much astonishment as himself. Its place he at once fixed with his instruments, and noted the fact with all its circumstances in his journal. The same star was observed by Cornelius Gemma, who had particularly examined that part of the heavens two nights previous, and was confident of its not being present then. It continued visible for the space of sixteen months, gradually diminishing in lustre, until it finally vanished in March, 1574. The brilliance of this star was so great as at first to cause Tycho's staff to deflect a shadow. Its light changed from white when the brightest to a yellowish hue, and afterwards had a fiery tinge like Mars, becoming livid like Saturn before its disappearance."

Edmonton,
Alberta.

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[2] *Astronomy, the History of its Discovery, and Description of the Scenery of the Heavens*, by Rev. Thomas Milner, M.A., F.R.G.S.

In Dreyer's *Tycho Brahe*, 1890, two chapters (44 pages) are devoted to the New Star of 1572.

REVIEW OF PUBLICATIONS

The Analytical Foundations of Celestial Mechanics, by Aurel Wintner. Pp. xii, 448; 6 x 9 ins. Princeton University Press, 1941. $6.00

This is not a book for the amateur astronomer, or even for the theorist interested primarily in the practical methods and results of celestial mechanics. Rather it is a book for the pure mathematician or the student of celestial mechanics who wishes to delve deeply into the rigorous mathematical foundations of his subject. Such topics as canonical transformations, classification of solutions, collisions and periodic orbits are dealt with at great length and with extreme rigour. The style throughout is that of the pure, rather than the applied, mathematician, and it is emphatically a book only for the advanced mathematical reader.

Although it is difficult to see what astronomical interest some of the results obtained can have, it is nevertheless obviously desirable to have the rigorous development of celestial mechanics pushed to its furthest possible extent, and there can be no doubt that the author has performed this task exceedingly well and most thoroughly. A summary of the most interesting results obtained, either at the end of the book or at the end of each chapter, would be an advantage to the reader who wishes to use it as a work of reference. Some historical notes and references are, however, included at the end.

A. F. Stevenson

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Morehouse and His Comet

The death of Daniel Walter Morehouse on January 21, 1941, brought sorrow to his numerous friends and admirers. Just two months earlier a letter from his secretary to the present writer said: "He has not felt well this fall. At the present time he is seriously ill with pneumonia, but daily slow gains indicate he will conquer the disease."

In *Popular Astronomy* for June 1941 Dr. Philip Fox gives an appreciative sketch of Morehouse's life. He was born at Mankato, Minn., on February 22, 1876. His childhood and youth were spent in Grant County, South Dakota, and in 1897 he entered Drake University at Des Moines, Iowa, from which he graduated in 1900. This well-known institution was founded in 1881 by the Disciples of Christ. Morehouse served it long and faithfully. He was instructor, professor, dean, and from 1923 president. During brief absences from his duties at Drake he pursued advanced courses of study and research, and in 1914 obtained the Ph.D. degree from the University of California. The subject of his thesis was: "The orbit of the Seventh Satellite of Jupiter."

An outstanding achievement of Dr. Morehouse's life was the establishing of the splendid observatory which serves Drake University and the municipality of Des Moines. It was well described in this Journal (vol. 16, p. 169, 1922), and the continued planning of its program and participation in its activities both on behalf of the students and the public afforded Dr. Morehouse great satisfaction.

The name of Morehouse became prominent through his discovery of a remarkable comet, and the circumstances as described by Professor Fox will be read with interest:—

> During the summer of 1908 Morehouse was at the Yerkes Observatory studying and participating in the observing program. Few visiting astronomers were privileged to use the Bruce Photographic Telescope. This instrument, really two photographic telescopes on a single mounting, presented by Miss Catherine Bruce of New York to Professor E. E. Barnard and by him to the Yerkes Observatory, was nevertheless regarded by Barnard as in his special

custody, and very few so won his confidence that they were accorded the privilege of using it. At the moment there comes the recollection of only S. A. Mitchell, Wilbur Cogshall, and D. W. Morehouse, who were so privileged. Not only was the instrument at Professor Barnard's pesonal disposition but, in using it, the Milky Way might not be trespassed on by others while the preparation of his great atlas was under way. On the evening of 1 September 1908 Morehouse had been assigned a region along the fringe of the Milky Way. Professor Barnard was one of the most generous of men, generous of his time, his personal interest, his material support. In recognition of his concentration on his problems it is easy to overlook or forgive his few foibles. In this case the result was that the photographs registered a superb comet.

In mid-morning on 2 September 1908, as I came down from the 40-inch dome where I had been working with the spectroheliograph, I met Morehouse as he came up from his dark room. There was excitement in his manner and voice, so much so that he scarcely whispered as he spoke: "Fox, I think I've found a comet." When I asked him if it appeared on both plates he rushed down to the dark room and in a moment returned to report the confirmation. It may be added that two nights later, 3 September, Borrelly independently discovered this comet.

Every comet has its peculiar characteristics but the Morehouse comet in behaviour proved to be the most bizarre, most whimsical, most unpredictable of any heavenly vagrant ever discovered. Its shape changing abruptly from night to night, or even hour to hour, made it of deepest interest. As Barnard wrote (*P.A.*, vol. 16, p. 596, 1908) "Transformations were so rapid that on 30 September there was almost no resemblance between the comet in the first picture and the last one of that night, an interval of less than four hours." Its behaviour upset some of the rather smug theories formulated to account for the more conventional changes of form. For this discovery Dr. Morehouse received from the Astronomical Society of the Pacific the customary award of the Donohoe Comet (*A.S.P.*, vol. 20, p. 286, 1912). With this comet the name "Morehouse" will go flaming through space for ages.

Dr. Morehouse was a charming man to meet. To everyone he radiated kindliness and unfailing courtesy—reflections from a deeply spiritual nature. He had a powerful physical frame which allowed him to be a leader in sports when a student, and throughout the following years he freely gave his strength, both of body and mind, to all worthy causes.

A Research Physicist's Views on Education

Sir J. J. Thomson, who was born December 18, 1856, and died August 30, 1940, was the outstanding leader in pure physical research

in the past generation. Clerk Maxwell, the first director of the Cavendish Laboratory at Cambridge University, England, was appointed Professor of Experimental Physics in March 1871, but the laboratory was not opened until October 1874. He served until his lamented death in November 1879. Lord Rayleigh, his successor, was elected in December 1879 and retired in the summer of 1884. In the following December J. J. Thomson, then only 28 years old, was elected,—he remarks, "to my great surprise and to that of everyone else." But no mistake was made. He entered Trinity College as a student in October 1876 and wrote on his final examination in January 1880. From 1880 to 1884 he carried on researches in the Cavendish Laboratory and then, as stated, he became Cavendish Professor. He held this position until 1918, a period of 34 years, when he retired to become Master of Trinity College.

From various countries budding physicists flocked to Cambridge to assist him in his exploration into the inner nature of the mysterious atom and his disciples around the world are still carrying on the work he began. It is quite natural that in his long experience with students from different lands he should think deeply on educational methods. Further, during the greater part of the years 1914-18 he was chairman of a Government Committee to report on the position of natural science in the educational system of Great Britain. The following quotations from his "Recollections and Reflections", which he completed in 1936, will be found interesting and well worthy of consideration. In the volume he presents many more matters from his varied experiences, and most of the scientific celebrities of the last eighty years are discussed in a discriminating but kindly way.

Educational Methods

I feel convinced that the best subjects for developing a boy's intelligence are those in which he is interested, and if he cannot find these in his school work, I think it better he should leave school and see whether he cannot find them in business, or in the workshop or the mill.—p. 226.

I think too much importance may be attached to the consideration of method. The personality of the teacher is the most important thing; a good teacher will soon find the method which in his hands will give the best results, and will do better with this than with one imposed on him from without.—p. 227.

Teaching and Research

Though eighteen hours a week spent in teaching may be thought to leave little time for research, I am strongly of the opinion that in general some teaching should be combined with research, and that the teacher should not regard his teaching as negligible in importance compared with his research. There is no better way of getting a good grasp of your subject, or one more likely to start more ideas for research, than teaching it or lecturing about it, especially if your hearers know very little about it, and it is all to the good if they are rather stupid. You have then to keep looking at your subject from different angles until you find the one which gives the simplest outline, and this may give you new views about it and lead to further investigations.—p. 82.

Educational Value of Research

In my opinion, research has great educational value and can be made a good test of a man's mental power. I have often observed very striking mental development in students after they have spent a year or two on research: they gain independence of thought, maturity of judgment, increased critical power and self-reliance, in fact they are carried from mental adolescence to manhood.—p. 283.

The West Point Method

I went to one of their classes [at West Point Military Academy]; there was a belt of blackboards round the room; in front of them, the cadets were standing at attention: the subject was mechanics. The instructor asked me if I would take the class, but naturally I asked to be excused. He then called on one of the cadets and told him to prove the formula giving the time of swing of the simple pendulum. He began, "I am requested to . . ." but he got no further, for the instructor rapped on the table with his gavel and said, "You're nothing of the kind, you are ordered—go on." He went on and repeated absolutely verbatim the proof given in the text-book; even the lettering on the figure was the same. This method of learning by rote seems contrary to any reasonable theory of education, but the irony of it is that it produces excellent results. So much so that there is a great demand for West Point men by large employers of industry throughout the country, and there is great difficulty in holding them for the army. The fact is that discipline is the keynote of the system.—p. 177.

Which seems to show that the method of procedure should be suited to the student and to the end in view. Any amount of psychological theory or of drilling in educational methods may be of little value. The successful teacher, besides of course having a thorough knowledge of his subject, must be able to determine for himself the best method of presenting the subject. What is best in some circumstances may be quite unsuitable in others.

The Moon and the Weather

The brief article on "The Moon and the Weather" in our last issue (page 227) brings forth a letter from a correspondent in western Canada who outlines the peculiar views of a friend of his, as follows.

> He freely admits that the "changes of the moon" have no connection with changes in the weather; neither does he think that the position of the horns of the young moon determine the amount of rain for the succeeding month. His theory is something like this: at the new moon he observes the general state of the weather, and particularly the direction of the wind. If the wind is in the north-west, or west (which generally means settled weather here) and especially if the weather is fine and settled at the new moon, he predicts that the weather for the succeeding month will be, in general, fine and warm. If, on the other hand, the wind is in the east, he predicts cold, unsettled weather.
>
> The novel feature lies in the fact that there is a sort of combination of a real astronomical event (the new moon) with the weather conditions at the place under consideration. Also, in this case, the predictions are not intended to be precise, but rather general. It may be argued that this last feature (like the ravings of the astrologers) leaves sufficient leeway for the prophet to be always right. However, I should like to see the tabulated results of a year's predictions and recorded observations at a place where careful observations are made, say, Edmonton or Toronto.

To the present writer the chief difficulty would be in deciding just what is to be tabulated. The time of new moon is a precise phenomenon but how shall we define the general state of the weather or the direction of the wind at that time and also the general nature of the weather during the following month? There would be plenty room for disagreement in the conclusions to be drawn. We shall consult an experienced meteorologist.

Personal Notes

Mr. John Patterson has been elected an Honorary Member of the Royal Meteorological Society. The high distinction of honorary membership in the oldest of meteorological societies is restricted to twenty who are, in the terms of the appointment, "eminent in Meteorological science".

Mr. Patterson has been at the head of the Meteorological Service of Canada since 1929. He was President of the Conference of Empire

Meteorologists in London, England, in 1935 and President of the American Meteorological Society for the year 1931. He has made numerous contributions to meteorology and science, the more extensive of which were the development of the anemometer and the study of upper air conditions over Canada. During the last World War he had a considerable part in developing the technique of separating, in large scale production, helium from natural gas.

Mr. Patterson is a graduate of the University of Toronto. He followed the Mathematics and Physics course and obtained the B.A. degree in 1900. Then he went to England and carried on research in the Cavendish Laboratory which he left to become professor of physics in the University of Allahabad, India, in 1902. There he remained until 1905 when he became meteorologist to the government of India and served as such until 1910. He then returned to Canada to be physicist in the Canadian Meteorological Service. He was made assistant director in 1925 and director in 1929, on the retirement of Sir Frederic Stupart. In a recent Government re-organization the title was changed to Controller.

Congratulations are tendered to Miss F. Shirley Patterson, whose home is in Newmarket, Ont. Miss Patterson obtained in 1935 the B.A. degree in the University of Toronto, together with the R.A.S.C. Gold Medal. She then acted as assistant in the Department of Astronomy and became M.A. in 1936. She entered Harvard University in September 1938, and at the June commencement this year was given the Ph.D. degree, the subject of her thesis being "Surface Photometry of External Galaxies." She has also been awarded by Radcliffe College the Caroline I. Wilby Prize for the best original work during the year in any department. Dr. Patterson is now on the staff of Research Enterprises Limited, Leaside, near Toronto.

Mr. Andrew F. Bunker, B.A. Ohio Wesleyan University in 1938, who has been an assistant in the David Dunlap Observatory during the last three years and obtained the M.A. degree from the University of Toronto in June 1940, has been appointed assistant at the McDonald Observatory, Fort Davis, Texas. Mr. Bunker's home is in Concord, N.H.

C. A. C.

MEETINGS OF THE SOCIETY

AT VICTORIA

January 22, 1941.—In the Recreation Rooms of the Y.W.C.A. The President, Dr. R. M. Petrie, was in the chair. Miss Hailstone called the attention of members to the publications *Popular Astronomy*, *The Telescope* and *The Sky*, to which our library subscribes.

The following were elected to membership in the Society: Messrs. H. D. Day and E. Eckley.

Continuing the business, the president reminded members of the telescope making section; Mr. Peters gave a summary of current phenomena; and Dr. Pearce reported on the award of the first Chant Medal to Mr. Bert Topham of Toronto for his work on variable stars and on meteors.

The lecture of the evening was given by Mr. Gordon Shaw who had chosen for his subject "The Planet Saturn". As an introduction, the speaker described the encounter theory of the origin of the solar system whereby a star made a close approach to the sun and attracted a large tidal filament from the outer layers of the sun which eventually formed the solar system as we know it today. The physical elements of Saturn and its orbit were presented in a manner easy to remember by the use of the figure 9: its distance is 9½ A.U., its diameter is 9 times that of the earth, its mass is 95 times that of the earth, and there are nine satellites. An interesting account of the discovery of the first satellite was given: Huygens, a famous student of optics, knew that there were six planets but knew of only five satellites. In order to remove this asymmetry, he looked for a sixth satellite and found it moving around Saturn. Then, having restored the symmetry of the solar system, he made no effort to find other satellies.

The rings of Saturn have always been its most famous characteristic. Galileo discovered them in 1610 and called them "ears" but could not explain their disappearance a few years later. Huygens noticed this in 1655, explained it as due to the inclination of the planet and predicted a similar phenomenon in 1671. The structure of the rings was finally proved in 1899 when Keeler obtained spectograms of the planet and showed that the planet did not rotate as a solid, and accordingly must be made up of many tiny particles.

In conclusion, Mr. Shaw presented his philosophy that the mind is far greater than the physical universe. Astronomers, by exploring the bounds of the universe, do still more in their penetration of the fog of ignorance and superstition. The material of the universe is great, but greater far is the mind which conceives it.

Following the lecture, the audience asked many questions concerning Saturn: the nature of its light, the thickness of the rings, the crape ring, and the constituents of its atmosphere. At the conclusion of this period a very hearty vote of thanks to the speaker was moved by Mr. Brydon. The meeting adjourned at 9.40 p.m.

KENNETH O. WRIGHT, *Recorder*.

The Royal Astronomical Society of Canada

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R. K. YOUNG,
Director, David Dunlap Observatory

Richmond Hill, Ont.